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Energy-saving biomass stove

Bếp tiết kiệm năng lượng dùng nguyên lý khí hóa trấu

Short communication

Hoang, Tri*

Hochiminh City University of Technology and Education, Vietnam

This paper introduces an energy-saving biomass stove. The principle of energy-saving biomass stove is gasification. It is a chemical process, transforms solid fuel into a gas mixture, called (CO + H_2 + CH_4) gas. Emission lines in the stove chimneys typically remain high temperatures around 90^0 to 120^0C. The composition of the flue gas consists of combustion products of rice husk which are mainly CO_2, CO, N_2. A little volatile in the rice husk, which could not burn completely, residual oxygen and dust will fly in airflow. The amount of dust in the outlet gas is a combination of unburnt amount of impurity and firewood, usually occupied impurity rate of 1 % by weight of dry husk. Outlet dust of rice husk furnace has a normal size from 500µm to 0.1 micron and a particle concentration ranges from 200-500 mg/m^3. Gas emissions is created when using energy-saving stove and they will be used as the main raw material in combustion process Therefore the CO_2 emission into the environment when using the stove will be reduced up to 95% of a commonly used stove.

Bài báo giới thiệu một bếp tiết kiệm dùng năng lượng sinh khối. Bếp tiết kiệm năng lượng thực hiện nguyên lý khí hóa sinh khối. Đó là một quá trình hóa học, chuyển hóa các loại nhiên liệu dạng rắn thành một dạng hỗn hợp khí đốt, gọi là khí Gas (CO + H_2 + CH_4). Dòng khí thải ra ở ống khói của bếp thông thường có nhiệt độ vẫn còn cao khoảng 90^0 ~ 120^0C. Thành phần của khói thải bao gồm các sản phẩm cháy của trấu, chủ yếu là các khí CO_2, CO, N_2, một ít các chất bốc trong trấu không kịp cháy hết, oxy dư và tro bụi bay theo dòng khí. Lượng bụi tro có trong khói thải chính là một phần của lượng không cháy hết và lượng tạp chất không cháy có trong củi, lượng tạp chất này thường chiếm tỷ lệ 1% trọng lượng trấu khô.Bụi trong khói thải lò đốt trấu thông thường có kích thước hạt từ 500µm tới 0,1µm, nồng độ dao động trong khoảng từ 200-500 mg/m^3. Lượng khí thải được sinh ra khi sử dụng bếp tiết kiệm năng lượng, sẽ được dùng làm nguyên liệu đốt cháy chính của quá trình đó. Do đó lượng khí CO_2 thải ra môi trường khi sử dụng bếp tiết kiệm sẽ được giảm xuống 95 % so với sử dụng bếp thường.

Keywords: biomass stove, energy, gasification, rice husk, CO_2 emission

1. Structure and principles

1.1. Structure saving stoves

The energy-saving stove using biomass consists of the following components (Figure 1):

+ Container materials (1), (2), (3), (13), (14)
+ Tank Air Purifier (5)
+ Stove (8), (9)
+ Valve system (4), (6), (10), (12)
+ Gas Pipeline System (7)
+ Air supply fan (11)

1.2. Principles saving stoves

Based on the principle of incompletely burning of fuel in the hypoxia environment to produce gas for cooking, the gas generated in the combustion chamber will pass through the filter and follow the stove pipe to the kitchen.

* Corresponding author
E-mail: hoangtri@hcmute.edu.vn

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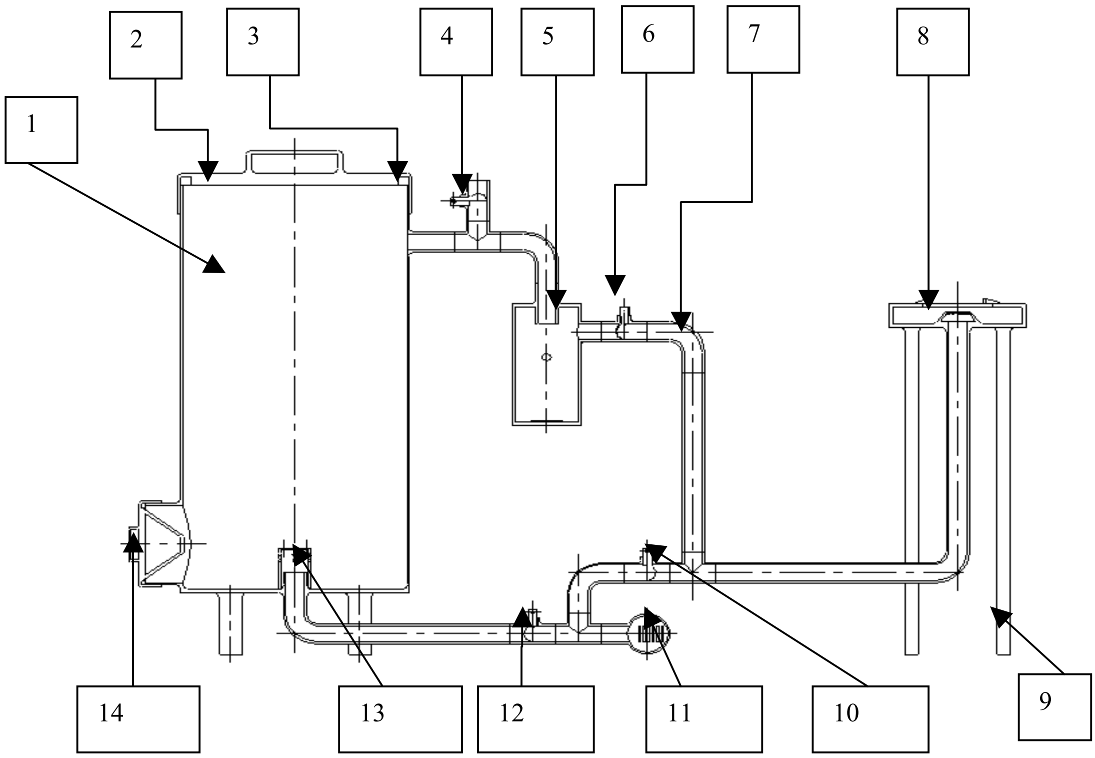

Figure 1: Energy saving stove

2. Selection and calculation of parameters of the stove

The main raw material is rice husk.

Table 1. Composition of elements in raw materials (%) [1]

Kind of materials	The elemental composition						The calorific value (MJ / kg)	ρ (kg/m^3)
	C	H	O	N	S	ash		
Sawdust	39.6	5.2	34.4	0.36	0	14	17.56	190
Rise husk	38.5	5.7	39.8	0.5	0	15.5	15.3	150
Straw	39.2	5.1	35.8	0.6	0.1	19.2	15.8	

Table 2. Airflow components out of various fuels (%) [4]

Kind of materials	CO	CO_2	CH_4	H_2	N_2	HHV	LHV
Sawdust	30.00	1.52	1.68	6.80	60.0	5.520	5.315
Rise husk	16.10	27.53	0.95	5.60	50.00	3.240	3.089
Straw	15.20	12.70	0.65	11.45	60.00	3.770	3.515

HHV: maximum temperature values; LHV: minimum temperature values

2.1. Diameter of the combustion chamber: D

$$D = \left(\frac{1.27 \times M}{SGR}\right)^{0.5} = \left(\frac{1.27 \times 12}{110}\right)^{0.5} = 0.38 \approx 0.4 \quad (m).$$

where:

M: the mass of material contained in the chamber (kg).

SGR= 110 ÷120 (kg/m^2) Speed gasification separate

2.2. Height of the combustion chamber: H

We have husk density in its natural state is 100 ÷ 120kg/m^3. But to improve our performance of gas in the combustion chamber we have to compressed gas creates 135 kg / m^3.

So: every 150 kg of rice husk will occupy 1m3.
Inferred 12 kg of rice husk will occupy 0.08 m3.
Inferred combustion chamber volume is 0.1 m^3.

$$V = \frac{\pi D^2 H}{4} \rightarrow H = \frac{4V}{\pi D^2} = \frac{4 \times 0.08}{3.14 \times 0.4^2} = 0.7\, m$$

With V = 0:08, it will hold 0.08x190 m3 = 15 kg of saw-dust.

2.3. Amount of air required to burn 1 kg of material

From the combustion reaction, we can calculate the amount of oxygen necessary to infer the amount of air required.

For carbon: $C + O_2 \rightarrow CO_2$
It means: 1 kmol C +1kmol $O_2 \rightarrow CO_2$ 1kmol
or: 12kg C + 32kg $O_2 \rightarrow$ 44kg CO_2
From the reaction we see, to burn 1kg C need 32/12 = 2.67 kg or 22.4 / 12 = 1,866 m^3 of oxygen. So to burn 1kg of H2 need 16/2 = 8 kg or 11.2 / 2 = 5.6 m^3 of oxygen.

Hence, to burn 1 kg of fuel which contains of C, H_2, O_2, meaning to burn 38.5% kg C, 5.7% kg of H2, it will need [38.5% C x 1,866 kg + 5.7% H 2 x 5.6 kg] m^3 oxygen. However, the available oxygen amount in the fuel is 39.8% or 39.8% x kg (22.4 / 32) = 0.7x39.8% m^3 so the amount of oxygen needed to burn 1 kg of fuel is:

$$V_{oxy} = \left(\frac{38.5}{100} \times 1.866 + \frac{5.7}{100} \times 5.6 - 0.7 \times \frac{39.8}{100}\right) m^3$$

In the air, the oxygen amount occupies 21% by volume so the volume of sufficient air for completion of combustion of 1 kg of fuel is:

$$V_{kk} = V_{oxy} \times \left(\frac{100}{21}\right) = 0.0889 \times 38.5 + 0.2666 \times 5.7 - 0.0333 \times 39.8$$

$$= 3.5 \frac{m^3}{kgnl} \approx 3.5 \times 1.29$$
$$= 4.5\ kg(gas)/kgnl$$

2.4. Flow of air required for combustion in the combustion chamber materials

$$Q = \frac{\varepsilon \times FCR \times SA}{\delta_a} = \frac{0.4 \times 3.5(\frac{kg}{h}) \times 4.5}{1.25(\frac{kg}{m^3})} = 5.04 \left(\frac{m^3}{h}\right).$$

where:
Q: gas flow in the combustion chamber (m^3/h)
ε: equivalent rate of 0.3 ÷ 0.4
FCR: The amount of material consumption (kg/h).
SA: Percentage of raw material / air 4.5kg gas / kgnl.
δ_a: Density of air 1,5 kg/m^3 (kg/m^3).

2.5. Gas velocity through the chaff husk

$$V_s = \frac{4 \times Q}{\pi \times D^2} = \frac{4 \times 6.3\left(\frac{m^3}{h}\right)}{\pi \times 0.4^2\,(m^2)} = 40.1\left(\frac{m}{h}\right) = 1.12(cm/s).$$

where:
VS: gas velocity through the chaff husk (cm /s)
Q: Flow rate of combustion air flow (m^3/h)
D: diameter of the combustion chamber (m)

2.6. Determination of combustion heat losses

For the design basis for combustion air supply fan, to the extent we went calculations determining losses in the combustion chamber.
Losses were calculated:

$$h_L = \xi_L \times \frac{V_K^2}{2} \times (1 + \beta \times t), \quad mmH_2O$$

where:
Vk: airflow velocity through the chaff, m / s
ξL: coefficient of resistance of the fuel layer, depending on the standard of ξL Reynollds
t: temperature inside the gasifier, ^oC

With fuel is rice husk combustion temperature in the range of 700 ÷ 1200 ° C, together with the coefficient of heat transfer by natural convection of air α = 0.2 ÷ 0.5.
We choose t1 = 900^{o}C.
β: coefficient of air temperature.

$$\beta = \frac{1}{173 + t} \frac{1}{K}$$

Standards Reynolds

$$Re = \frac{v_K \times d}{\Upsilon}$$

where:
d: diameter of the gas-chamber, m
ϒ : kinematic viscosity of the gas flow, m^2 / s
v: velocity of the air flow, m / s
Looking up tables kinematic viscosity of specialized books, at a temperature of 900 ° C, we found the air kinematic viscosity υ = 185,7.10^{-6} m^2 / s.

$$Re = \frac{0.021 \times 0.4}{185.7 \times 10^{-6}} = 45.4 > 7$$

Since Re > 7 (turbulent flow) should have:

$$\xi_L = \frac{1800}{Re} + \frac{46}{Re^{0.08}} = \frac{1800}{37.3} + \frac{46}{37.3^{0.08}} = 73.5$$

Then go through the obstacles in the fuel chamber:

$$h_L = 73.5 \times \frac{0.21^2}{2} \times \left(1 + \frac{1}{273 + 900} \times 900\right) = 2.86\ mmH_2O = 28.1 \quad Pa$$

2.7. Capacity fan

$$N_k = k\frac{Q \times P}{1000\eta} = 1.1\frac{5.04 \times 28.1}{1000 \times 0.65} = 0.23kw$$

where:
k: reserve factor - 1.1
Q: Air flow (m^3/ h)
P: pressure gas line (Pa)
N: Fan efficiency - 0.65

2.8. Capacity of motor

$$N_k = \frac{N_k}{0.98} = \frac{0.23}{0.98} = 0.23 \quad kw$$

3. Comparing price

In the same amount of 9 kg of rice husk, the time for using traditional stoves is 57 minutes, but it is 2 hours 58 minutes for the saving stoves.

Thus, to satisfy the demand for a day according to the above calculation, we need to 9kg husk for saving stove. For traditional stoves, it will need 28kg. It means saving stoves will reduce 19 kg of rice husk per day. The saving amount will be equivalent to 13.3 thousand per day if using saving stoves.

The price of a saving stove is 2,500,000 VND in the market. The payback time is about 6 months

3.1. Operating instructions

Input materials can be: rice husk, sawdust, firewood, straw, leaves, etc. Outputs: gasification.

3.2. Manipulation of the stove

Step1: Preliminary test stove
Check the tightness of the pipe.
Combustion air supply valve to open, the valve remains in the closed state.

Step 2: Pour the water into the air filter until the water flow from the small drain hose Then locking back the tube to prevent water flowing out.

Step 3: Burning fire.
Put the ingredients into one-third stove.
Scratch off material from the ash removal door to make room to set up the stove.
Turn on gas supply fan at the highest level.
Proceed up the stove.

Step 4: After about 2 minutes was found with coal, raw materials continue to fill the kiln (about 10 cm from kiln top to create a stable air gap).
Note: the material should compress slightly on the raw rice husk, straw. For sawdust does not need compressed.

Step 5: Cover the combustion chamber. Wait approximately 3-4 minutes, open fire test valve to check the stable smoke. If the amount of smoke is a lot and stable then they can be used.

Step 6: Open the gas supply valve to the stove, ignition proceed. After strong fire open oxygen valve to adjust the flame.

Step 7: Rake out the ashes after each cooking before begin to the new batch.

3.3. Stove Maintenance Guide

• Checking whether the pipeline is congested by turning on the fan and opening, closing the valves. Regularly checking the smoke pipes to prevent leakage
• When you see an adhesive in the combustion chambers and dusts need cleaning immediately, to avoid smoke and flue.
• When the fan is still operating normally, but does not take the wind into the stove, turn off the fan for cleaning.
• Change the water in the air filter after 2 -3 times use.

3.4. Safety conditions while using stove

• We need to locate the combustion chamber away from the kitchens and places where people move regularly to avoid being burned by the heat of the stove.
• When we start cooking, we need to wear protective masks to avoid the dust and smoke.
• Lock the valves carefully when not in use.
• Do not open the lid of slag when the blower switch is active to avoid burns or stove dust flew out. The flue pipe joints must be sealed.

4. Conclusion

The result of understanding the current use of rice husk obtained some southern delta provinces such as An Giang, Can Tho, Kien Giang, and the central provinces such as Binh Dinh, Quang Ngai, Phu Yen etc. A portion sold to people do cooking materials, compost, and most physical dump polluting the environment. There are no measures to use this natural resource in a reasonable manner.

From this we draw some conclusions as follows:

- Vietnam has a geographical location that provides favorable climate conditions for agricultural development. Due to the industrialization process, the area of agricultural land is gradually shrinking, though agriculture still plays an important role in attracting labor.
- The source of biomass energy, which is generated from the agricultural by-products in general and husk in particular, is not collected and used effectively.
- Theoretically, practical experiments show that using energy saving stove and normal stove using rice husk require the same material inputs, but the operating time of saving stove increases three times compared with normal stove's. The heat produced of saving stove is larger than normal stove.
- In terms of environmental protection, the energy-saving stove plays a huge role in reducing the amount of CO2 emitted to the environment than the stoves using biomass energy.

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